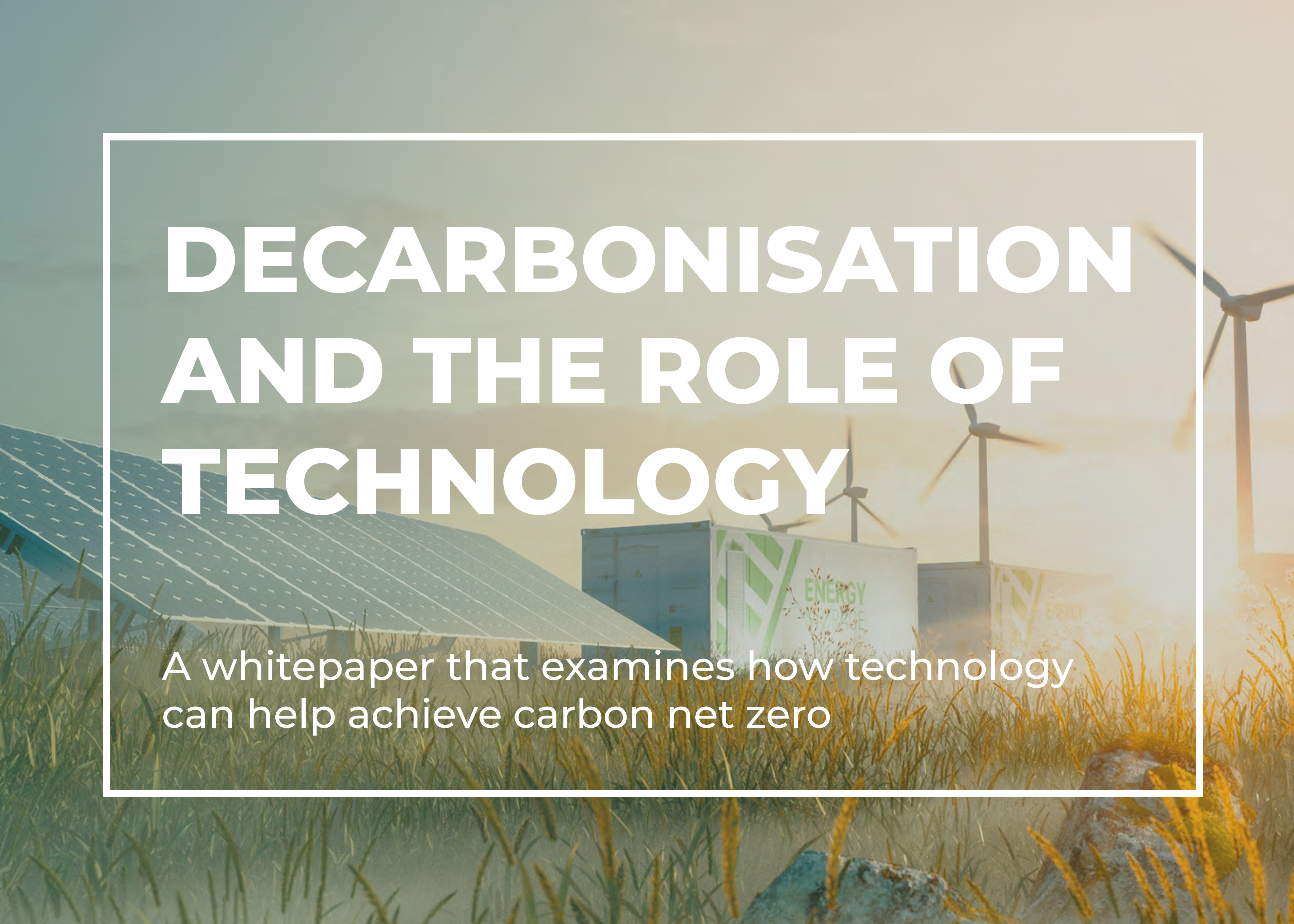

DECARBONISATION AND THE ROLE OF TECHNOLOGY

A whitepaper that examines how technology can help achieve carbon net zero

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The authors do not necessarily have any affiliation with Intel Corporation. Intel is one of a number of contributors.

Robert Hall
Executive Director, Resilience First

June 2021

Resilience First is a not-for-profit membership organisation which has the aim of advancing resilience in business communities and society.

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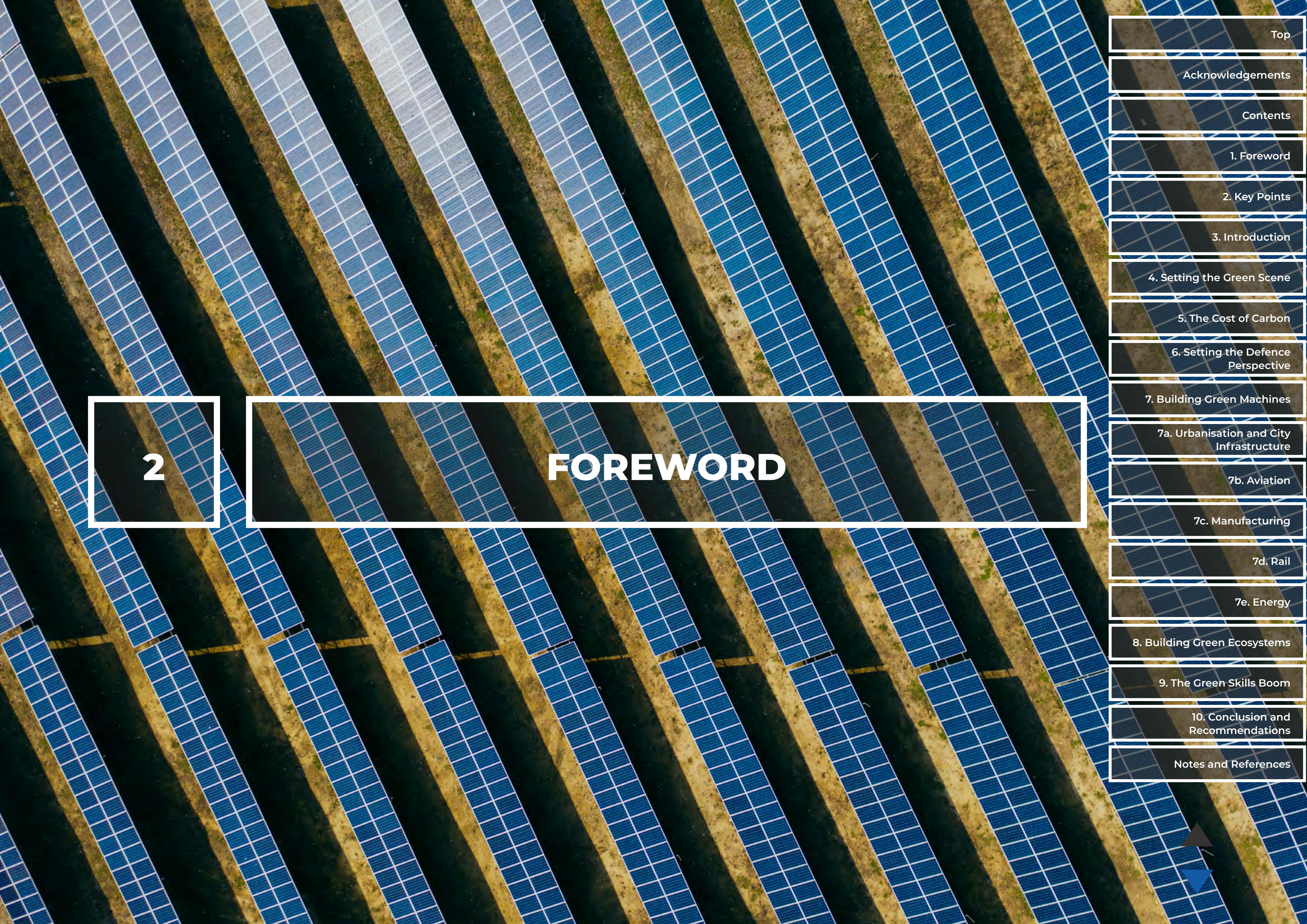

2 FOREWORD

By Shirley Rodrigues

The Mayor of London has just been re-elected on a manifesto that includes a 2030 net-zero carbon target and, as he starts his second term, he does so with an even greater determination to lead a green and fair recovery from the pandemic.

As we confront the challenge of the pandemic together, we must not forget that the climate crisis is an ever-present threat to our economy, our wellbeing and the fate of humanity. We must kick-start and then support our economic recovery, enabling the just transition and creating the green jobs and skills needed for the future, with a clear focus on tackling the climate emergency and creating a fairer and more resilient economy.

It is essential we focus on the communities and individuals that will need the most support as we decarbonise our economy. To gain support from across society we must demonstrate that a prosperous recovery, a just recovery and a 'green recovery' are not exclusive but one and the same. We can deliver economic opportunity and jobs for Londoners whilst tackling our environmental challenges.

The scale of the challenge is unsurpassed and the solutions are multi-faceted, whether retrofitting buildings, decarbonising our energy and transport systems, or transitioning our economy and how our businesses operate.

The role of technology is critical to this effort. But we cannot rely on technologies yet to be invented given the time left to act on the climate emergency. We must use every lever including demand reduction, behavioural change and investment. One thing, though, is clear, we need to work together across all sectors of society and at speed. We have no time to waste.

By Adrian Criddle

For more than 50 years, Intel has had a profound influence on society, broadly focused on three areas: being a catalyst for technology innovation and products that revolutionise the way we live; harnessing the breadth and scale of our reach – through people and partners – to have a positive effect on business, society and the planet; and pushing ourselves and the industry on corporate responsibility, environmental sustainability and diversity and inclusion.

Hence, Intel is pleased to team up with Resilience First to help create this important whitepaper on decarbonisation and the role of technology. The subject is vitally important for Intel, its customers, its suppliers and the wider world. We see technology as being an essential component in helping achieve net-zero carbon emissions across multiple sectors. In a series of four webinars with Resilience First in March 2021, we together explored how four industry sectors were using technologies to progress decarbonisation.[ii]

This whitepaper extends the webinar sessions by looking at topics such as defence, energy and skills. It is a comprehensive review which adds weight to, and insight on, the many aspects of decarbonisation. Intel is delighted to be able to support the valuable contributions to this paper as well as highlight the positive impact of our innovative processes in creating world-changing technology that enriches the lives of every person on earth.

2 KEY POINTS

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The main points addressed in this whitepaper are:

Technology can help with decarbonisation in four key areas: adaptation, renewables, energy efficiency, and carbon removal. While progress has been made in all these areas over recent years, the speed of delivery needs to accelerate. Innovation is key in not only major industry sectors like manufacturing and aviation but also defence and the built (urban) environment, particularly energy consumption. Meeting net-zero targets by 2050 is possible and can be achieved through a combination of technology, innovation and behavioural change. *(Section 3)*

While innovation will play a significant role in enabling the UK and the world to achieve net zero, there are plenty of technologies available today that can help to move the needle and mitigate climate change so it is critical that governments and societies deploy these technologies urgently and follow a 'learn-by-doing' approach. *(Section 4)*

Partly driven by regulatory demands as well as by investor and consumer pressure, there has been a significant shift in corporate awareness about climate-change risks. Indeed, corporate recognition of climate change as an issue has increased on the whole, with an emphasis on awareness, assessment and disclosure to meet global Paris targets and fulfil mandatory climate-risk disclosure requirements. Particularly in the context of the quest for a net-zero economy, many corporates are adopting ambitious emission-reduction targets. *(Section 5)*

Defence can do much to reduce its emissions through its engagement with industry and the development of technology, from the needs of equipment, buildings and even our farmers and land managers. Defence has always embraced and often led technological development. The current situation is no different and defence should be at the forefront of the technological revolutions that are happening in every area, thereby reducing emissions and enhancing the capability to remain the effective fighting force that is required. *(Section 6)*

Energy use in buildings accounts for the majority of greenhouse-gas (GHG) emissions in most cities and is a significant source of air pollution. Existing buildings are often one of the biggest opportunities because there is much that can be done to improve them. Improving the energy efficiency of these buildings through retrofitting (e.g. new insulation and cladding, replacement windows, replacing building services) can often deliver significant emissions reductions. *(Section 7a)*

Of the levers available to decarbonise aviation, the two most important and impactful ones are alternative fuels, and future aircraft propulsion technology. Other levers include airspace redesign and infrastructure developments to optimise aircraft operation in the sky and on the ground. Even with the carbon reductions gained from these solutions, there will be residual carbon from flying which needs to be mitigated through market-based measures such offsetting as well as natural and engineered carbon removal. These measures will not be a replacement for in-sector efforts. *(Section 7b)*

> ...corporate recognition of climate change as an issue has increased on the whole, with an emphasis on awareness, assessment and disclosure to meet global Paris targets and fulfil mandatory climate-risk disclosure requirements.

UK manufacturers must integrate net-zero measures into their strategies to build a more resilient and sustainable future. Manufacturers are agile and maintain the ability to manufacture the products that the economy needs at any time: it is part of the sector's resilience and has been highlighted during the ongoing Covid-19 challenge. However, government policy and the investment and tax regimes in particular will play a key role in the speed of transition to alternative net-zero measures. ***(Section 7c)***

For the rail sector, technology centred on renewables can play a significant part in reducing carbon emissions from large-scale power generation contracts to small-scale local power generation within the network e.g. solar panels at stations. The rail network has been mapped remotely and technology is now been used across the estate to identify opportunities for renewable technology integration. ***(Section 7d)***

The energy system is one of the most complex machines in the world to rebuild as a green machine. It also needs to do so without being stopped. The entirety of the technological fabric of our energy systems from oil, gas, electricity and other vectors such as heating and cooling, all need to be reintegrated into a new operational model. By definition, there cannot be any one system architect for this. ***(Section 7e)***

The confluence of organisational partnerships, transparency in the use of data enforcement standards, and the connectivity of ecosystem of players is going to shape future relationships between public and private actors. This confluence will contribute to the building of green ecosystems designed to reduce environmental impact of products and services. ***(Section 8)***

Just as we require a blended mix of energy solutions, we must adopt an attitude of blended development for the workforce to support its emergence. Delivery of skills-broadening programmes that supports the existing workforce to adapt to new technologies will be required. Concurrently, education and training programmes for new entrants into the workforce should incorporate the knowledge, skills and behaviours related to green-energy solutions. Through these programmes, we can enhance the learner's opportunities to build a career in a carbon-neutral society. ***(Section 9)***

3 INTRODUCTION

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Decarbonisation is the global challenge of this generation and of future generations. If solutions are not found and implemented urgently, the threat of worldwide excess temperature rise in the coming decades presents an existential threat to the planet we inhabit: that threat surpasses the pandemic, international terrorism or trade conflicts. It is paradoxical that the very core of life – carbon – is now the key ingredient of the danger to life – carbon dioxide (CO_2). Perhaps it is symbolic that carbon is also the sole constituent in the most highly priced commodity in the world – diamond.

The challenge is to wean ourselves off carbon misuse. There has been progress in some quarters. The UK, for instance, has decarbonised its power grid faster than any other European country since 1990 – down 44% according to official figures. This is largely because of the decommissioning of many of its coal-powered power stations. With the passing of the Climate Change Act in 2008, Britain became the first country in the world to commit to legally binding carbon-emission reductions. The UK's 'Ten-Point Plan for a Green Industrial Revolution'[iii] announced in November 2020 has accelerated the momentum. The Conference of the Parties (COP) 26 in November 2021 may present an opportunity to be grasped.

Yet, speed is of the essence in decarbonisation. Nations do not have another two decades to enact further pedestrian changes in energy production and consumption. To be carbon neutral by 2050, and keep the earth's mean temperature below 2°C of pre-industrial levels, the world must curb emissions by 7.6% a year for a decade. The size of this goal can be set against global emissions from fossil fuels and cement production alone in 2019 which were 16% higher than in 2009. Delaying the challenge will only add to the bill in the end.

Yet, out of the 2,000 world's largest publicly traded companies by sales, only a fifth have set net-zero goals, according to the Energy and Climate Intelligence Unit. In fact, only around a quarter of companies that have set net-zero goals include emissions across all 'scopes' including Scope 3 emissions in the value chain such as those customers using their products.[iv] Off-setting targets through, for instance, carbon credits that pays for emission cuts elsewhere will not be enough to achieve more urgent emission reductions.

This is where technology can help. While there isn't a two-shot vaccine yet available to achieve decarbonisation, technology can make significant inroads to tackling the problem. There are four main places where greenery meets technological change and that can make a big difference to our responses.

First, there is adaptation which is an essential component of resilience in the round. Adaptation involves change – both physical and behavioural – to adjust to actual or expected climate and its effects. It is about not only building higher flood walls, for example, but also employing new materials that can dry out quickly or using satellite imagery to feed sensors that can more accurately map flood-drainage options.[v]

Second, there are renewables, one of several mitigation measures to address the underlying causes. Harnessing wind, solar, and hydro-power has allowed the UK to move away from fossil fuels sooner than would otherwise be the case. The economics have shifted so that wind is now the default source particularly for a cloudy, crowded island like the UK (creating around 25% of power generation, with only 4% coming from solar). Technologies that feature better ways of storing energy are valuable in such circumstances, namely through improved batteries, new forms of electrolysis and green-hydrogen generation.

Third, there are improvements in energy efficiency. In a scenario where the 2°C goal is met, greater efficiency could cut emissions by 7 gigatonnes by 2040, about the same as renewables, according to the International Energy Agency. By installing a micro-grid, sensors that switch off unwanted lights and machines, and smart-energy monitoring systems, some companies have reportedly been able to reduce energy costs and carbon emissions by almost a half. Digitisation of transportation and routing is another way forward.

> While there isn't a two-shot vaccine yet available to achieve decarbonisation, technology can make significant inroads to tackling the problem.

Last but not least, there is carbon removal – carbon capture, usage and storage (CCUS) in full. Between 100 billion and 1 trillion tonnes of CO_2 will have to be removed from the atmosphere by 2100 if the 2°C goal is to be reached, according to the UN Intergovernmental Panel on Climate Change. Technologies to help achieve this exist and are getting better, whether through Direct-Air Capture (DAC) or techniques like accelerated mineralisation.

This whitepaper looks at the place technologies can take in the struggle to get to net zero and beyond. It is a compilation of articles by experts in their respective fields. There is a mixture of industry-specific examinations with a broader look at the costs, skills and ecosystems. It begins by setting the scene and considering the costs of inaction.

4 SETTING THE GREEN SCENE

Meeting net-zero targets by 2050 is possible and can be achieved through a combination of technology, innovation and behavioural change. The concept of 'net zero' revolves around the principle that it is not possible to remove all greenhouse-gas (GHG) emissions on this timescale, so economies need to ensure as many applications and sectors achieve zero GHG emissions as possible, and then offset the remaining emissions through both natural and technological carbon-capture approaches.

To meet net zero, society and industry will need to adapt, more energy efficient technologies will need to be deployed, the use of renewables in the energy and power sectors will need to increase, clean energy carriers such as hydrogen will be required, and carbon-capture technologies will need to be optimised and deployed at scale.

Change for the better

Adaptation and behavioural change cover a multiplicity of approaches, including moves to more local production and consumption of goods, and reductions in the number of flights taken, minimising the energy and emissions associated with the movement of goods and people. Allied with an increase in active travel (e.g. walking and cycling), greater use of public transport is another significant needle mover where incoming technologies such as batteries and hydrogen fuel cells will enable zero-emission buses and trains to reduce societal energy consumption.

Existing technologies and continued innovation will help to increase further the trends towards reducing waste, re-use and recycling, with the latter being facilitated by technologies enabling the recycling of, for instance, plastics not currently recycled or the replacement of such plastics in packaging, etc. The recycling of critical raw materials such as precious metals and, for example, the nickel and cobalt used in batteries, will become increasingly important in minimising CO_2 emissions associated with the extraction of raw materials.

Significant land use changes will also play a key role, enhancing current natural carbon sinks by planting more trees and restoring peatlands – the latter are among the most valuable ecosystems on Earth, being critical for preserving global biodiversity, providing safe drinking water, minimising flood risk and helping to address climate change by absorbing CO_2.

A final societal adaptation point is the need to accelerate the trend for diets to move from meat and dairy towards more plant-based products, reducing methane emissions from livestock.

Quick wins

There are some quick wins in energy efficiency and deployment of low-carbon technologies through improving the insulation of buildings, both domestic and industrial, and continuing to increase the efficiency of new, internal combustion engine-powered vehicles (and using increasing levels of sustainable liquid fuels within them) and industrial processes.

In parallel, substantial gains in the carbon inventory will be achieved by moving new cars, vans, buses and trucks to low-carbon solutions – mainly battery-powered in the case of cars, with heavy trucks more likely to be powered by hydrogen fuel cells using low-carbon hydrogen. The UK has committed to phasing out the sale of new cars and vans with internal combustion engines by 2035 and will shortly consult on when to do this for heavy goods vehicles (HGVs).

Associated with these developments, recycling of critical raw materials such as nickel and cobalt (from batteries) and platinum (from fuel cells) are essential as we look to minimise the carbon footprint of these incoming technologies. In addition, the carbon footprint of aviation can be significantly reduced by moving from fossil-based kerosene to Sustainable Aviation Fuels (SAF) made from either biomass or power-to-liquid technology, and perhaps by using hydrogen in the longer term.

Industrial processes, such as those involving high temperatures based on the combustion of natural gas or coke/coal, need to transition to low-carbon hydrogen as this is the best fit for rapid at-scale decarbonisation.

For domestic heating there needs to be a shift away from natural gas-powered boilers to electric heat pumps and hydrogen-based boilers, using low-carbon hydrogen. Technological advances will further improve the overall efficiency of these incoming solutions. There is an interesting parallel to transport decarbonisation here in that using renewable electricity is the first option to investigate, as it will almost always give the highest efficiency.

However, energy efficiency is not the only consideration. In the case of HGVs, the batteries required to give the required driving range would be very large, heavy (and therefore reduce the payload of the truck) and expensive, and would take a long time to recharge – reducing vehicle utilisation. Hydrogen fuel cells for HGVs on the other hand are much lighter and the range of the vehicle is only limited by the size of the hydrogen storage tank. In addition, the hydrogen can be replenished in several minutes.

In the case of heating, electric heat pumps are more efficient but are expensive and will be difficult, if not impossible, to install in a significant proportion of the existing housing stock. On top of this, the amount of electricity required to heat homes in extreme cold snaps, such as the 'Beast from the East' storm in 2018, would mean building massive excess capacity into the renewable electricity network which would be redundant most of the time. The ease of storage of large quantities of hydrogen to be despatched in such cases makes this a sensible approach to deploy in a two-track strategy with electric heat pumps as part of the national strategy.

Johnson Matthey has set out plans to capitalise on the emerging market for green hydrogen via water electrolysis using renewable energy.

There are two commercialised electrolysis technologies: alkaline water and Proton-Exchange Membrane (PEM) electrolysis. The company is focused on the latter which uses a membrane coated with iridium and platinum catalysts to split water into hydrogen and oxygen. Where PEM electrolysers are used, it will be important to recycle the platinum and iridium used in the electrolysers which is an area in which the company specialises.

Johnson Matthey is focussed on manufacturing this key component for PEM electrolysis at scale at their plant in Swindon. The plant can currently produce key components for PEM systems to enable tens of megawatts of hydrogen production, enough to power several thousand homes, and will soon be in a position to manufacture components enabling giga-watts of green hydrogen to be produced.

Increased deployment of renewables

The cost of low-carbon electricity continues to fall as a result of increased deployment and technology advances in wind and solar power. While energy efficiency will continue to increase across the usage sectors, new demands from transport, building heat and industrial processes will lead to significant increases in overall demand by 2050 – estimated to be between two and three times the current UK demand by the Climate Change Committee. It is expected that off-shore wind will be deployed to meet a large proportion of this demand, with the UK Government having set a target of 40 giga-watts of off-shore wind by 2030.

> It is critical to understand that failing to act on climate change will cost us more than the anticipated costs of deploying these technologies...

This additional renewable capacity will be used both directly to electrify cars, high-speed rail lines, domestic heating, etc, and indirectly to generate some of the clean hydrogen needed to decarbonise the more challenging applications such as HGVs, shipping, parts of industry and some heating applications. Some of this clean hydrogen will also be generated by reforming natural gas with downstream carbon capture and storage, where future innovations in catalysts, materials and process technology will further minimise the CO_2 emissions of this approach.

Carbon capture at scale

If we are to meet net zero, it is essential that carbon capture is deployed at scale, including from high CO_2 point sources and Direct-Air Capture (DAC) from the atmosphere. The former has been successfully demonstrated using a range of technologies (the first large-scale application of carbon capture and storage was in 1972), while the latter is still in its infancy and requires innovation to increase efficiency and uptake which will, in turn, reduce costs due to economies of scale. As outlined above, carbon capture at high efficiency is a key requirement for the generation of clean hydrogen from natural gas – class-leading processes today can capture over 95% of the CO_2 generated by the process, and such technologies will be deployed in the UK in the coming years e.g. HyNet hydrogen hub project in the northwest of England.

Land-use changes are another strong carbon capture tool, including tree planting and the repurposing of land to, for instance, reclaim and manage peat bogs sustainably. Innovative low-carbon farming practices, such as soil regenerative agriculture, including soil, fertiliser, manure management and carbon sequestration, will need to be widely adopted.

Final word

While innovation will play a significant role in enabling the UK and the world to achieve net zero, there are plenty of technologies available today that can help to move the needle and mitigate climate change, so it is critical that governments and societies deploy these technologies and follow a 'learn-by-doing' approach. This will bring three major benefits: increased deployment will lead to supply-chain development and growth, driving down costs; reduced carbon emissions in the short term to provide lots of data to guide future innovation and technology development; and a very good economic return on climate stabilisation investments.

It is critical to understand that failing to act on climate change will cost us more than the anticipated costs of deploying these technologies: the Energy Transitions Commission estimates that reaching net-zero CO_2 emissions by 2050 would cost around 1.5% of global GDP, while the Economist Intelligence Unit estimates that, based on current trends, the fallout of warming temperatures would reduce global GDP by 3% by 2050 due to increased drought, flooding and crop failures.

5 THE COST OF CARBON

Climate change is already disrupting the economic, social and natural systems we depend on. Floods, storms, heatwaves droughts and sea-level rise pose risks to global food security, infrastructure and jobs, as well as to human health, livelihoods and ecosystems around the world. According to the most recent Global Assessment Report on Disaster Risk Reduction (GAR19), 'climate change is increasing the risk of disaster – amplifying existing risk and creating new risks including the direct consequences of a warming planet – with cascading consequences in the short, medium and long term.'[vi]

These impacts are unevenly distributed around the world, with some countries, regions, communities and sectors facing far greater risks than others. For example, half the world's megacities, and almost 2 billion people, are located on coasts and exposed to several climate hazards including sea-level rise. Even if global warming is restricted to just below 2ºC, as is the ambition of the Paris Agreement, scientists expect sea-level rise to reach around 30-60cm by 2100 resulting in significant economic damage and migration. This could rise to around 60-110cm with further dramatic impacts if greenhouse-gas (GHG) emissions continue to increase strongly.[vii]

To calculate the costs of these changes economists tend to use a top-level, global average in relation to Gross Domestic Product (GDP) as a measure of economic performance.[viii] However, these aggregate economic calculations do not represent all risks and impacts. They are subject to significant uncertainty and usually do not reflect specific impacts on sectors, communities or individuals. One study suggests unmitigated global warming could reduce average global incomes by roughly 23% by 2100, and make 77% of countries poorer in per capita terms than they would be without climate change. Other assessments suggest that if the global average temperature increase is kept below 2°C, it will cause economic impacts that are less than 1% of global GDP.[x]

Many businesses and industry sectors are already being impacted negatively, as shown globally by the McKinsey Global Institute[xi] and for the UK by the UK Climate Change Risk Assessment.[xii] For companies operating in the UK the main climate risks arise from flooding of business sites; damage and infrastructure disruption from coastal change; water scarcity; risks to finance, investment and insurance including access to capital for businesses; reduced employee productivity due to infrastructure disruption and higher temperatures in working environments; and disruption to supply chains and distribution networks. *(See Figure 1)*

Figure 1:

Top six areas of inter-related climate change risks for the UK

Flooding and coastal change risks to communities, businesses and infrastructure (Ch3, Ch4, **Ch5**, Ch6)	MORE ACTION NEEDED
Risk of health, well-being and productivity from high temperatures (**Ch5**, Ch6)	MORE ACTION NEEDED
Risk of shortages in the public water supply, and for agriculture, energy generation and industry (Ch3, **Ch4**, Ch5, Ch6)	MORE ACTION NEEDED
Risks to natural capital, including terrestrial, coastal, marine and freshwater ecosystems, soils and biodiversity (**Ch3**)	MORE ACTION NEEDED
Risks to domestic and international food production and trade (Ch3, Ch6, **CH7**)	MORE ACTION NEEDED
New and emerging pests and diseases, and invasive non-native species, affecting people, plants and animals (Ch3, **Ch5**, Ch7)	RESEARCH PRIORITY

NOW -----► **RISK MAGNITUDE** -----► **FUTURE**   LOW   MEDIUM   HIGH

However, there are also opportunities for business from changes in demand for goods and service. The upcoming third Climate Change Risk Assessment ($CCRA_3$) – due for publication in June 2021[xiii] – is investigating current and future risk trends and asks whether adaptation action is already in place. Early findings indicate that none of the current and future risks to business from climate change identified in $CCRA_2$ have decreased in magnitude.[xiv] This partly reflects an improved ability to assess and report these risks but it also reflects that business decisions

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continue to create additional risk by locking in increased exposure and vulnerability.

The impact of climate change on businesses manifests itself across three risk categories, as initially defined by the Bank of England in 2015 and formalized by the Task Force on Climate-related Financial Disclosures (TCFD):

- Physical risks are the first-order risks which arise from weather-related events, such as floods and storms. They comprise impacts directly resulting from these events, such as damage to property, and also those that may arise indirectly through subsequent events, such as disruption of trade, global supply chains and production processes or resource scarcity, impacting comparative advantage and productivity.
- Transition risks are the financial risks which could arise for firms from the transition to a lower-carbon economy and related regulatory changes, demand shifts and market implications. While the transition brings significant opportunities there will be negative impacts for those whose business models are ill-equipped for the low-carbon economy.
- Liability risks are risks that could arise from parties who have suffered loss and damage from climate change and then seek to recover losses from others who they believe may have been responsible. In addition, greater public scrutiny of corporate action and greenwashing can also leave corporates exposed to more lawsuits.

The exposure of business and industry to these risks depends on many factors, including location, type of activity, business model and size.[xv] Importantly, these impacts work through different channels and there are many interdependencies and thresholds that can lead to a significant rise in scale and magnitude of the risks. For example, changes in the natural environment do lead to shrinking natural capital with negative impacts, particularly on agriculture and fisheries but also on wider business sectors which depend on clean water and other ecosystem services. Additionally, most business functions depend on reliable infrastructure with disruptions a key risk for site operations, access to markets, supply chain and distribution networks. Similarly, employee productivity and staff wellbeing can be negatively impacted by heatwaves. Furthermore, international interconnectivity means that impacts on one part of a business's value chain can spread across and cause significant indirect disruptions and damages.

Partly driven by regulatory demands as well as investor and consumer pressure, there has been a significant shift in corporate awareness of climate-change risks: 'Climate change is becoming a defining theme of the global economy.'[xvi] Indeed, corporate recognition of climate change as an issue has increased on the whole, with an emphasis on awareness, assessment and disclosure[xvii] to meet global Paris targets[xviii] [xix] and fulfil mandatory climate-risk disclosure requirements.[xx] Particularly in the context of the quest for a net-zero economy, many corporates are adopting ambitious emission-reduction targets.

However, there are still significant imbalances with regard to performance and action to achieve these targets as, for example, highlighted by the recent report of the Transition Pathway Initiative (TPI)[xxi]. Also, many short-term business models are not geared up for dealing with risks of that scale – in the words of the CEO of investment firm BlackRock: '… companies must act now to step up their efforts to tackle climate change.'[xxii]

The market failure is particularly concerning because of so-called 'lock-in' effects: a decision today to invest in assets, design a product or locate a business site can lock in the investors or business to current and future climate risk that may be irreversible or costly to change later. This underlines the importance of not misunderstanding climate change as a distant problem but making it an essential component of current and future planning and decision-making.

6 SETTING THE DEFENCE PERSPECTIVE

Why defence?

For some, defence being involved in climate change is perhaps an alien concept: what's protecting our citizens got to do with the environment? For others, defence's role in climate change is an opportunity for militaries across the world to impose their will on their citizens – the 'securitisation of climate change'. For the vast majority, defence is viewed as no better than a fossil-fuel company as one of the largest greenhouse-gas (GHG) emitters. All these issues centre around one key debate: is climate change a price worth paying for security in an either/or situation?

It is a false and unnecessary debate, and it is not a zero-sum game. Put simply, climate change leads to a more unstable world – droughts, floods, rising sea levels and unpredictable weather patterns. The competition for resources, increased poverty and migration will lead to more conflicts that, in turn, reduce the ability of nations to deal with climate change, creating a vicious cycle and an ever-dwindling chance for humanity to address the threat to peace and security. This is already happening in vulnerable states that suffer from weak governance which increasingly become tinder boxes for radicalisation.

So, while some may not think it is relevant to defence, climate change will impact on world stability and geopolitical relationships, as is already happening with the opening of the sea lanes in the Arctic. As a global leader, the UK should be concerned and act to increase stability and peace as well as reduce its own emissions to a minimum, without damaging its ability to fulfil its purpose.

The challenge

The challenge that defence faces is not inconsiderable. The Ministry of Defence's (MoD's) Scope 1 and 2 emissions – mostly from military equipment and purchased energy respectively – represent half of central government's total. So, it is completely clear that if the MoD does not achieve net zero, the UK Government cannot either which is clearly unacceptable. If Scope 3 is included, defence represents nearly 3% of UK annual emissions. This is not surprising as defence is almost the last UK nationalised industry, operating across the globe with its own supply base, policies and processes and the 100,000 employed across the whole force.[xxiii]

Reducing emissions without damaging operational effectiveness is essential. It is also an unavoidable truth that there are some emissions that simply cannot be eradicated, even by 2050. (Retrofitting the aircraft-carrier engines which have an operational lifetime past that date, for instance, is simply infeasible.) The good news is that the MoD's rural estate can and must be used to drawdown the emissions that cannot be reduced or minimised. Embracing new technologies, particularly in the energy arena, not only helps reduce emissions but also may actually enhance operational effectiveness. To give an oft-quoted example, creating renewable energy for operational deployments reduces the demand on vulnerable (and enormously expensive) fossil-fuel supply chains, and allows defence to operate with much greater resilience.

The recently launched MoD climate-change strategy[xxiv] outlines the approach and includes:

- *Changing the relationship with industry* with, for example, contracts that consider emission profiles in the bidding process, to incentivise the development of minimal emissions in all equipment. Given the government has already stipulated 10% of bid criteria be based on social value, this is already within MoD's remit.
- *Building a commercial relationship* that demands that suppliers themselves are on the road to net zero and only accepts bids from companies that have a plan to reduce their, and MoD's, emissions – this is how those Scope 3 emissions can be tackled.
- *Helping lead a fuel revolution*. As an early indicator, the RAF has already agreed a protocol to allow the use of 50% Sustainable Aviation Fuels (SAF) by 2040. By the same token, defence must embrace developments that see new ships powered by lower emissions fuels. Elsewhere, electric and hybrid vehicles are attractive from both emissions and operational perspectives.
- *Recommending reducing* the size and weight of many equipment types by removing personnel from them – as has already been done with the drone fleet – and thereby make renewable energy more likely as a propulsion system. This has the added advantage of reducing potential loss of life.
- *Changing how training is undertaken*. Much can now be simulated with additional advantages beyond just reducing emissions. For example, flight simulators require fewer spare parts and maintenance, they can be pushed to the limit in a way that is undisclosed to an adversary, and they also reduce the number of aircraft required. Elsewhere, sophisticated game-type technology is already beginning to be used for land and sea simulation.
- *Reducing emissions from our buildings and rural estate*. As the seventh largest housing provider in the country, owner of about 100,000 buildings and responsible for almost 2% of UK landmass, the MoD has a huge opportunity. Solar farms are already being built for resilience and cost reasons, and net-zero buildings are being constructed with some ground-breaking designs that are even net negative. Soon, building standards will insist that all new builds are net zero. Similarly, many tenant farmers are keen to understand and embrace emission-free farming practices. The MoD will also use the estate to restore biodiversity and sequester carbon through afforestation or regenerating wild meadows, peat bogs and wetlands.

Technology will help

Defence can do much to reduce its emissions through our engagement with industry and the development of technology, from the needs of our equipment, buildings and even our farmers and land managers. Defence has always embraced and often led technological development. The current situation is no different and we should be at the forefront of the technological revolutions that are happening in every area, reducing emissions and enhancing capabilities to remain the effective fighting force it needs to be.

Leadership

Through partnership and the sharing of knowledge UK defence can also help other militaries meet the intertwined peace and climate-change challenge. When the world sees that its militaries understand that fates are intertwined on this issue and are themselves working to decarbonise their own complex operations, it sends a signal and acts as a further catalyst to wider society – all while encouraging a more peaceful future.

7 BUILDING GREEN MACHINES

7a. Urbanisation and city infrastructure

Bulging cities

Globally, we are in a period of rapid urbanisation. The urban population of the world has grown rapidly from 751 million in 1950 to 4.2 billion in 2018. In 2020, 55% of the world's population lived in cities, a proportion that is expected to increase to 68% by 2050 when another 2.5 billion people may have been added to urban counts.[xxv]

The global middle class is also growing. In fact, just over half of the world's population is today classified as middle class. In terms of human and economic development, this is good but it presents a challenge too. As people get richer, they consume more, causing more waste and more emissions: there is a straight-line correlation between consumption and greenhouse-gas (GHG) emissions.

When one sees these mega-trends in urbanisation it is easy to think that every city is growing but that is not the case. Annual urbanisation rates in some African cities like Lagos are running at close to 6% whereas cities like Kyoto in Japan have the reverse challenge, namely a declining and aging population and the erosion of social cohesion.

Whatever the starting point and context, cities all over the world now accept that they need reduce GHG emissions and increase climate resilience. The impacts of climate change through extreme weather are being felt by cities around the world. These impacts are hard hitting and are constantly filling our news channels.

The City of Houston, for example, experienced three 500-year flood events in the three years leading up to 2017. In 2019 Cape Town narrowly avoided Day Zero when it would have run out of drinking water. It is not alone in having water scarcity as a major risk on the city risk register – London, too, has this risk.

Urban heat is also being felt in cities. It is a major issue in Melbourne and is being addressed in London and Paris through the design of cool-spots or green-oasis school yards in order to create a summertime refuge from the heat.

There is clearly a need for rapid decarbonisation. Cities urgently need to position themselves on an ambitious emissions reduction trajectory to achieve net-zero emissions and climate resilience by 2050. Many are setting challenging interim targets for 2030: over 1,000 jurisdictions worldwide have now declared a climate emergency.

To have any hope of getting on to this pathway, a clear plan is required. This is typically referred to as a climate action plan. C40 Cities is currently rolling out a programme to deliver 95+ climate-action plans for mega-cities but this also happening in local authority areas, towns, regions and states around the world.

Some cities like Amsterdam are already beginning to address consumption and supply-chain emissions. In other cities, advocacy is beginning to take hold, promoting reduced air travel and a shift towards plant-based diets. Yet, it is important to keep in mind that most of the world's urban dwellers have never stepped onboard an aeroplane and many are undernourished without the luxury of considering a shift in diet. As climate action plans are developed, fairness and equity need to be kept in mind.

Improving buildings

Energy use in buildings accounts for the majority of GHG emissions in most cities and is a significant source of air pollution. Existing buildings are often one of the biggest opportunities because there is much that can be done to improve them. Improving the energy efficiency of these buildings through retrofitting (e.g. new insulation and cladding, replacement windows, replacing building services) can often deliver significant emissions reductions.

Municipal-owned buildings offer an opportunity for city administrations to show leadership. Yet, decanting these buildings for retrofitting when they attract good rental income often remains a challenge. Buildings in new developments are likely to have a life span of 30-50 years so it is important they are designed, built and operated in a way that minimises both the emissions embodied in the materials used in construction and the emissions from use.

In addition to high-energy performance in new and existing buildings, energy should be supplied by low-carbon and renewable means e.g. utilising waste heat through heating and cooling networks or employing ground-source heating and using wind and solar photovoltaics to generate power.

In the building and energy sectors there is a range of technological innovations or evolutions that can help. First, there are improved surveying technologies such as drones / aerial photography which allow remote inspections and thermal imaging that help to prioritise areas for intervention on the grounds of heat loss. There are networking and mapping tools that together with citizens, communities and businesses help spot opportunities for more efficient use of buildings such as the extended schools' model.

Street- or district-level, demand-side management that reduces demand peaks has long been considered a solution with the potential to drive down energy use and carbon emissions. This links to controllable appliances and to building management systems. Zero-carbon (or green) hydrogen through electrolysis is hailed as one solution for zero-carbon heating and is currently being piloted for use in homes.

There are also promising technologies to reduce emissions from each of the three top-emitting industries: cement, iron and steel, and chemicals and plastics.

Technology is also improving efficiency in design and manufacture, driving reductions in material waste, substituting low-carbon for high-carbon materials, and promoting circular economy interventions. Importantly, technology is helping to monitor success and learning. There is a well-known phenomenon in buildings called the performance gap based on the fact that buildings do not deliver in practice what they were designed to deliver. The National Australian Built Environment Rating System (NABERS)[xxvi] has recently been launched in the UK and aims to address this problem, giving building owners a clearer view of how their buildings perform.

Transport savings

Transport is the fastest growing source of GHG emissions in most cities and is a leading sources of local air pollution. The key to a successful strategy that reduces transport emissions is the reduce, avoid, shift, improve and adapt framework. Through this, the aim is to reduce the number and distance of trips through compact and connected urban planning.

This aim can be achieved by shifting trips to zero- and lower-carbon modes such as walking, cycling and public mass transit, improving the efficiency of remaining vehicle fleets (e.g. encourage zero-emission vehicles via electrification, including shared electric vehicles (EVs)) and ensuring the transport infrastructure is resilient to the impacts of climate change. It is important to stay focussed on this framework as EVs do have an environmental impact through manufacture, braking and tyre wear. Only through reducing cars on the road do you achieve the wider urban planning and congestion benefits.

Technology can support in a range of ways – from phone apps like City Mapper, Ordnance Survey or Slow Ways – through to linked, agent-based modelling to make transport services run more smoothly. Apps can also enable the use of shared EVs and can double up as a pass or payment for public transport. The app in this case is critical as it is important that shared EVs link seamlessly with public transport to ensure smooth integration and to ensure EVs are not replacing trips that would otherwise be achieved by public transport.

The power of data to help decarbonisation

By 2025 the world will have produced 175 zetta-bytes of data – that's a trillion giga-bytes. That amount of data requires an enormous amount of computing power and as Intel provides this computing power at the core of a vast amount of technology it is vital that their chips work as efficiently as possible to consume as little energy as possible.

Bringing together diverse data sources, such as the Xprotect open platform by Milestone Systems, allows diverse technology systems to connect. This can help with decarbonisation by allowing city infrastructure to connect with business infrastructures thus enabling the 'smart city'.

Agent VI's video analytics can help implement traffic management, smart buildings and waste management. The technology enables existing cameras to be used to provide more powerful data.

Carbon capture

Whatever a city does with buildings, transport, waste and urban planning, it will almost certainly be left with some residual emissions, namely those emissions that the city is unable to eliminate through reduction, efficiency or renewables. This is where carbon capture comes in.

There are several different approaches to carbon capture e.g. Direct-Air Capture (DAC), deep-sea storage, etc. Yet, for some city clients, the only method they are really investigating is natural eco-sequestration through tree planting or rewilding projects.

Planning these projects is not straightforward. One needs to find sites, and work up the most appropriate planting scheme by considering not only the carbon benefit but also other factors like biodiversity, flood attenuation, etc. Funding needs to be found as well as verifying the carbon sequestration through the Woodland Carbon Code or similar guidelines.

Many cities are considering where they can use existing land or acquire new land for the purposes of carbon sequestration. For instance, the multinational brewery and pub chain BrewDog is buying up a thousand hectares in Scotland but they are not the only ones.

Technology can play a role around land regeneration too. Technology will be deployed for site location, for mapping landcover and biological mass and hence carbon sequestration through rewilding, or for testing soil conditions. There will also be the need for technological systems to be put in place to monitor the sites from security, biodiversity and air-quality perspectives.

Adapting for the future

In all the sectors covered, alongside the interventions to reduce GHG emissions, there are additional measures that can be taken to support adaptation and resilience.

Retrofitting buildings can enhance flood resilience or reduce summer overheating, even where this is not the primary driver for the retrofit. Reducing the number of cars on the road can free up space for parking or urban-greening projects – creating more permeable areas, which can double as summer cool spots. Eco-sequestration schemes can be designed with flood alleviation, biodiversity or community participation in mind, like the Community Forests in the UK.

Co-benefits do not need to be limited to improving physical climate resilience. The measures or interventions might also support health and wellbeing outcomes such as more walking or cycling and time outside, or deliver economic or social benefits through job creation or skills development.

In conclusion, cities play a critical role in responding to global threats such as the climate and ecological emergency but they need to face these challenges whilst also responding to the day-to-day needs of their residents, ensuring investments return tangible benefits, and that benefits are felt equitably.

There are some well-established sectors that cities can and should focus on to reduce GHG emissions and enhance climate resilience.

City administrations have a unique role as convenors. It is their role to bring together all the actors necessary to deliver on a climate action plan from across business, community and civil society. This includes providers of technological solutions. Technology has a place in supporting decarbonisation and resilience across each of these sectors. Yet, it is important to ensure it is not technology for the sake of technology but that it clearly responds to the critical climate-change drivers and opportunities.

7b. Aviation

Pulling levers

Global aviation contributes around 3-5% of the total warming effect that causes climate change and in 2019 contributed around 2.5% to global human-made CO_2 emissions. While this is a small impact compared to many other industrial sectors, the growing demand of aviation around the world and specific challenges the sector faces in reducing emissions means that aviation's contribution to climate change could be much larger in future.

The urgency of climate change demands that aviation accelerates the work it is doing to ensure cleaner more sustainable flight. The challenge gives a shared sense of purpose to the sector to work towards this cleaner future. The pathways to reaching net zero 2050 are clear.

Of the levers available to decarbonise aviation, the two most important and impactful ones are alternative fuels and future aircraft propulsion technology. Other levers include airspace redesign and infrastructure developments to optimise aircraft operation in the sky and on the ground. Even with the carbon reductions gained from these solutions, there will be residual carbon from flying, which needs to be mitigated through market-based measures such as offsetting, in addition to natural and engineered carbon removal. These measures will not be a replacement for in-sector efforts.

It is only through a combination of all of these levers, delivered through strong collaborations between industries and governments, catalysed by investment and policy, and enabled through international approaches, that the ambitious but achievable goal of net-zero aviation will be reached by 2050.

The UK aerospace industry is committed to playing a leading role in decarbonising aviation through the development of advanced aircraft and propulsion technology. It is already investing billions in R&D towards that aim, and stands ready to do more.

UK leadership

The UK became one of the first major economies to enshrine net-zero GHG emissions into law. Through the UK Sustainable Aviation coalition of aerospace manufacturers, airlines and airports, the industry was the first in the world to commit to net-zero carbon by 2050. Other countries have followed suit, including the European aviation industry through its Destination 2050 strategy, and more are expected to align in the coming months.

Through the Aerospace Growth Partnership (AGP) – a collaboration between UK aerospace and government – the Aerospace Technology Institute (ATI) was established to co-invest £300m per year in green aerospace technology. The ATI programme is delivering innovative, world-leading technologies including composite aircraft wings, ultra-efficient jet engines and digital manufacturing capabilities to reduce energy and material usage and design ever-more efficient aircraft components.

More recently, the establishment of the Jet Zero Council is bringing together Ministers and senior leaders from across aviation to map out a new path towards truly sustainable aviation and net-zero emissions flight, and to drive the collaborative efforts needed to achieve this. The realisation of this ambition will demonstrate global leadership and create thousands of high-tech green jobs in every region of the UK.

UK aerospace has exceptional industrial strengths in every region and nation. Pioneering capabilities exist across the UK from high-tech propulsion technology and precision engineering to wings of the future, fuel systems and power electronics. The aerospace industry is committed to working with government and the wider industry to achieve the Jet Zero Council's ambitions and goal of net-zero emissions for UK aviation by 2050. The industry has a clear and credible plan on how to achieve this, through:

- Continued development of state-of-the-art aircraft and engine designs in a relentless pursuit of near-term fuel efficiency improvement and CO_2 reduction.
- Increased use of sustainable, alternative aviation fuels to deliver significant emission reductions over both the short and long term.
- Radical and disruptive third-generation new aircraft and propulsion technologies to move into the age of zero-emission flight, exploring the power of hydrogen and electricity.

What next?

With public, governmental and investor focus aligned on climate change, raised political ambition through initiatives like the Jet Zero Council coming to the fore, and industry's commitment to improving aviation sustainability, now it's time to act with purpose and ambition.

In order to bring the aviation industry's ambitions and proposed activities together, a draft UK Aviation Net Zero Action Plan has been developed. The Action Plan reflects the collective views of aerospace manufactures, airports, airlines and air-traffic control. It highlights the key milestones – industry actions, public investments and policy measures – that need to be executed in order to deliver UK net-zero aviation by 2050.

The plan relies on industry investing in future aircraft technology supported by government through the ATI and policy support for the commercialisation of Sustainable Aviation Fuels (SAF). The commercialisation of radical new technology including hydrogen and electrification will also require additional ATI funding and policy support.

The Jet Zero Council goals will only be achieved through a collaborative approach which incentivises, enables and supports investment in critical capabilities in the UK. Achieving these goals will enable the UK to be a global leader in sustainable aviation and will capture significant industrial value from this transition. The aviation industry believes that a shared Action Plan between government and industry will give the UK a leading position in decarbonising flight. Industry is enthused by the government's desire to increase the UK's level of ambition and will work with government to deliver on it.

The UK's major international leadership role with the Presidency of COP26 in 2021 presents a unique opportunity to set out its collective stall and demonstrate the industry's ambition, capability and strategy to deliver sustainable aviation solutions to the world.

An ambitious Jet Zero agenda will enable UK aerospace to build back better, greener and faster. It will create highly skilled, high-value jobs; secure the future of thousands of engineers; and build a path to recovery for the aerospace industry and other parts of the UK aviation sector.

Flying taxis take off

Because of better batteries and lightweight materials, flying taxis are appearing in the skies ready to carry passengers. Around 300 companies are working on short-range, battery-powered craft that take off and land vertically, according to one consultancy. Midway between a cab and a helicopter, multicopters have distinct advantages over both. Quiet electric motors allow frequent, carbon-free travel. They can fly several times faster than a cab and need little space from which to operate.

Volocopter, a German company backed by two car firms, Daimler and Geely, as well as Intel and DB Schenker, hopes to fly in 2023 and begin services soon afterwards. Volocopter's VoloCity is much quieter than helicopters generating only 65dB, which is similar to a passing car, thereby reducing urban noise pollution as well.

7c. Manufacturing

High demand

There is no denying that the manufacturing sector is energy intensive with the cost of energy representing over a fifth of overall operating costs. All manufacturing facilities have boilers, conveyor belts, compressors, turbines, pumps and tools, which burn fossil fuels and consume electricity. The manufacturing industry is indeed reliant on energy to function normally.

This is inherent in any production of goods, just as we all are and will always be reliant on energy to heat our buildings or to move around. So, it is not a question of whether, for instance, freight transportation (road or shipping) is needed or not but what types of fuel these modes of transport rely on and how easily they can transition. Shipping, as an example, only makes up 3% of carbon emissions but it is one of the more difficult-to-decarbonise industries.

Unfortunately, a significant proportion of energy is wasted in manufacturing because it comes from old or leaking equipment – whether compressors or pumps – and that most of the heat produced by the machinery is not recycled, hence is lost. The sector has tended to 'sweat' existing assets rather than invest in latest technology to the same extent as other countries.

As a result, manufacturing is a major carbon emitter, making up 12% of the total emissions produced in the UK. Yet, the sector represents 53% of the UK's total exports, 10% of GDP and 65% of research and development (R&D).

Reliance on energy cannot and will not change but what will change is which types of energy are used i.e. fossil fuels or renewables. Hence, the sector welcomes initiatives like the Clean Maritime Demonstration Competition and the work of the Jet Zero Council on sustainable aviation fuel, zero-emission aviation and aerospace technologies.

Manufacturers are agile and maintain the ability to manufacture the products that the economy needs at any time: it is part of the sector's resilience and has been highlighted during the ongoing Covid-19 challenge. However, government policy and the investment and tax regimes in particular will play a key role in the speed of transition to alternative net-zero measures.

Industrial digital technologies

Manufacturers are at the beginning of the fourth industrial revolution. Industrial digital technologies will play a central role in improving manufacturing efficiencies, reducing waste and optimising freight flows and, therefore, they are key enablers for moving towards sustainable manufacturing.

The manufacturing sector is very diverse in the UK. It plays host to some of the largest manufacturers who are great technology adopters and world leaders in innovation. At the other end of the spectrum, there are many small- and medium-sized enterprises (SMEs) which still do not adopt new digital technologies at speed, even though they acknowledge the benefits of doing so. If they are not supported to overcome these barriers, there is the risk of creating a bigger productivity gap between those firms that are adopting technology and those that are doing nothing.

Recent research from Make UK showed that 71% of manufacturers are planning to increase spending on industrial digital technologies in the next two years and two-fifths of manufacturers are planning to invest in green technologies. It is vital that such plans translate into action.

Not only would such measures spur much needed investment in capital expenditure in the immediate term but in the mid-to-long term it would also support the efforts of government and industry to achieve net zero and, hence, position the UK as a leader in digital manufacturing.

Digital infrastructure underpins the economic, cultural and social infrastructures to develop places where people want to live, work and visit. For businesses, this is crucial to more

Creating energy-efficient manufacturing

With a limited amount of renewable energy sources, it is important to use as little energy as possible. In a typical manufacturing setup, there are many diverse ecosystems that produce data but need to be interconnected to drive efficiency and reliability. Data are also important to enable manufacturers to be agile. Artificial Intelligence can be a vital tool in analysing incoming data and providing scalability to systems by constantly making adjustments as necessary.

TCS Clever Energy's technology helps businesses manage energy use and emissions. One product is designed for buildings and manages electricity, gas and water consumption, and another is for industrial usage and measures air, gas and steam in addition.

The technology collects data from a range of sources and analyses it using a 'digital twin' and historical data. The 'golden cycle' can then be predicted that achieves maximum energy efficiency without affecting the quality, using intelligent tariff management and benchmarking.

productive economic activity: that is why 69% of manufacturers said that they plan on investing in their IT infrastructure in the next 12 months. As a result, 41% of manufacturers said the government should prioritise digital connectivity in towns and rural areas in order to unlock productivity but, crucially, drive greater innovation.

The national rollout of 5G and ultra-fast broadband must occur within the next two years. The success of local economies depends on all businesses using the best digital technology and data to drive innovation, resilience and productivity. Better digital infrastructure can support manufacturers to become more productive and competitive. Moreover, without the basics such as 5G, full digital adoption will be out of reach for many manufacturers. Taking these, what may appear simple, steps would have a huge impact on manufacturers across the UK.

The role of R&D

In order for technology to play a prominent role in decarbonisation, a greater focus has to be placed on innovation and especially R&D. It is concerning that Covid-19 will lead to reduced spending on R&D in the next two years. This will have knock-on impacts in future years.

Manufacturers need to see a significant uplift in private-sector R&D spending: this is needed to deliver the UK Government's 2.4% GDP target. Government must improve the effectiveness of the R&D tax-credit scheme by simplifying the application process, speeding up payment as well as doubling the R&D tax-credit expenditure.

It is certainly good news that a £375m fund has been announced in the March 2021 Budget to help scale up the 'most innovative, R&D intensive businesses.' However, help should not just go to the most innovative projects but also to R&D, feasibility and up-scaling projects. It needs to be recognised that established installations, which are not necessarily conducting R&D projects but simply changing to be more energy efficient and/or using electric-powered equipment, are a key part of the manufacturing sector's contribution to net zero. This recognition would lay the foundations that the UK needs to ensure manufacturers are the creators and makers of the future and in the best position to be world leaders in green technology.

Despite the Covid-19 crisis, manufacturers have grasped that the green industrial revolution is one of the major opportunities – if not the only one – to rebound from the pandemic and build a future resilient economy. While they are rethinking their businesses post-Covid and responding to the new EU-UK Trade and Co-operation Agreement and new global trading opportunities, it makes complete sense for manufacturers to integrate net-zero measures now into their strategies to build in a resilient and sustainable future.

They know they have a pivotal role, not so much because they will, of course, have to decarbonise but, most importantly, because they will be the ones producing the next generation goods, providing the services and adopting the agile business models needed to transition into the low-carbon economy. The pace of product development on new green technologies is high. Hydrogen fuel cells, expansion of offshore wind, carbon capture use and sequestration, and electric-vehicle (EV) production are some of the higher profile examples.

However, manufacturing is a complex web of supply chains and for these new technologies to go into full-scale production companies must support the supply chains to make the transition. An example is in the EV market. We hear much talk about battery production in the UK and the government supporting giga-factories. However, there is a whole suite of complex components which are needed to produce an EV: the question is how do we transition existing suppliers who manufacture internal combustion engines or gearboxes to make new generation components? We need a long-term industrial policy.

A contribution

Make UK has been keen to guide and help its members as the net-zero challenge has become one of the long-term, top priorities on the agenda of many manufacturers. It has been busy setting up a net-zero framework with a set of guiding principles, a toolbox with resources to enable companies to get started or accelerate their pace, and a series of demystifying net-zero educational workshops.

In addition, Make UK will be working on an ambitious sectoral roadmap that sets out how to meet the target within the manufacturing industry. It will, of course, be liaising with other sub-sectors that may already have or are building theirs in order to ensure overall coherence. It is also supporting the UK's official promotion campaign for COP26 (Race to Zero) by encouraging SMEs to sign up to the SME Climate Hub.

From a technology perspective, Make UK is engaging with its membership on various thought-leadership pieces and looking to identify key barriers around the adoption and implementation of digital solutions across the sector. This complements our work around the net-zero challenge.

COP 26 will showcase Make UK's members during a dedicated manufacturing session to demonstrate the pace and ambition of the sector's transition to a sustainable economy. It will highlight the fact that manufacturers play a crucial part in helping everyone achieve net zero through the development and application of world-leading technologies, services and business models to lead the green revolution.

Over the course of the last year, manufacturers have been incredibly flexible in trying to help the country's national interest by repurposing or increasing their production of essential equipment, products and services. But no one should forget, despite these difficult times, about the long-term future and this means continuing on our journey towards sustainability and becoming a net-zero economy.

Improved battery materials are key to successful decarbonisation

Batteries are a key enabling technology for successful decarbonisation of society. The swift implementation of EVs has been a driving force for battery development, centred around high capacity and low cost. However, for the decarbonisation to be successful, electrification must be extended beyond EVs, requiring custom-made technologies for other applications.

One drawback of current battery technology which impedes their implementation in, for example, electric trains, buses and ferries, is that they charge too slowly. TioTech has develop new titanium-anode materials for lithium-ion batteries (LIB) which can be safely charged to 80% in six minutes, an operation taking 25-30 minutes in current batteries.

Batteries that can be charged 10,000 times or more, three times the industry standard. Extended lifetime reduces the environmental footprint of batteries, contributing to sustainable electrification. Storage solutions for renewable energy and smart-energy grid applications value a long lifetime.

7d. Rail

The future is rail

The railway is on a journey to a cleaner, greener future. Rail is already seen as an environmentally sound form of travel, contributing less than 1% of UK annual GHG emissions. More can and should be done to make rail the greenest and most reliable form of public transport to aid in the green economic recovery as well as connecting communities across Britain.

The annual impact of the UK railway is estimated at 9.5 million tonnes of carbon.[xxvii] This essentially comprises three main elements: carbon embodied in the materials used in new infrastructure projects, enhancements and renewals (55%), traction diesel (20%) and traction electricity (10%).

Network Rail published its ambitious Environmental Sustainability Strategy in September 2020. This sets out a pathway to achieving a sustainable railway and to achieve net-zero carbon emissions by 2050 (and 2045 in Scotland).

The strategy has four key pillars: a low-emissions railway, a reliable railway that is resistant to climate change, improved biodiversity of plants and wildlife, and minimal waste and sustainable use of materials.

The strategy sets clear and tangible milestones to becoming carbon neutral but we have to keep pace with significant advances and investment in other modes of transport by improving our environmental credentials.

To support this journey, Network Rail is extremely proud that it recently became the first railway organisation in the world to commit to the most ambitious science-based targets for carbon emissions aimed at limiting global warming to 1·5°C rather than the 2°C adopted in the 2015 Paris Agreement. The UN-backed Science Based Targets Initiative has independently verified our targets and our plans to achieve them.

The company has committed to: reduce absolute Scope 1 and 2 GHG emissions by 46% by 2029; reduce absolute Scope 3 indirect emissions by 28% by 2029; and ensure that 75% of suppliers by emissions (covering purchased goods and services and capital goods) will have science-based targets by 2025.

However, this ambition cannot be achieved alone. The rail sector has to be pulling in the same direction in order to find creative engineering solutions and clever ways to reduce the energy consumed.

Suppliers generate about two-thirds of the railway's emissions, so Network Rail is working with the wider supply chain, such as manufacturing and construction companies, to give suppliers confidence that the company is serious about making the changes needed.

Spending and activity data with thousands of suppliers has been analysed and has identified the 81 most significant contributors who account for 75% of total supply-chain emissions.
The company is implementing a dedicated relationship management programme focused on supporting them.

The network has recently rolled out a dedicated decarbonisation programme across our regions with 11 initiatives that will significantly contribute to carbon-reduction targets. This includes transitioning the road fleet to ultra-low emissions vehicles, installing charging points, and identifying opportunities to generate renewable electricity on its land using solar and wind farms to feed energy directly into the rail network.

Railways save 1.2bn tonnes of carbon per year

If all services carried out by rail were moved to other forms of transport there would be an increase of annual carbon emissions globally of 1.2bn tonnes - this is equivalent to Africa's total emissions.

Carbon emissions on the railways can be reduced by the better use of data. Tracking trains can provide data to improve performance and provide information for passengers. A project in San Diego that alerted travellers who were using the car of the fact that using a train would get them to their destination more quickly. Others are using technologies to monitor air quality and biodiversity, while better signalling technology can help reduce the number of times trains have to stop, hence saving energy.

The company already buys electricity from either renewable or low-carbon sources but there is more to be done to cut our energy use and emissions.

Technology centred on renewables can play a significant part in reducing carbon emissions through large-scale power generation contracts to small-scale local power generation within the network e.g. solar panels at stations. The rail network has been mapped out remotely and technology is now being used across the estate to identify opportunities for renewable technology integration.

More efficient timetabling, better-designed infrastructure, and more intelligent use of capacity will also help drive down emissions. At present, around 42% of the rail network is electrified and towards the end of last year an interim business case was published for the Traction Decarbonisation Network Strategy. This recommended a steady transition of the remaining diesel trains to electric, battery and hydrogen fuel cells. The strategy was prepared by a cross-industry initiative which has been working collaboratively and constructively to assess the issues and options, and advise government on setting the future direction of travel.

Material innovation and reuse of materials need to come to the fore to reduce the embodied carbon of the materials used. The company has already launched a low-carbon catalogue featuring low-carbon solutions for existing projects such as platform renewals. These materials are now available to projects across the UK helping to reduce carbon emissions by up to 30% initially compared to the existing materials used. New, large-scale rail projects across the UK are also addressing their environmental impacts and utilising new technology.

Carbon impacts are a growing part of our project life-cycle approach. The principles of PAS 2080 (Carbon Management Standard) from the early phases of our engineering projects are increasingly being applied. Environmental assessments are a core requirement of projects. When it comes to roof-renewal projects, managers are considering installing solar panels rather than just replacing with like-for-like materials.

Network Rail is also working with the Department for Transport and the Infrastructure and Projects Authority to implement new whole-life carbon requirements to large-scale projects from the beginning of 2022.

Technology is key

The network can also make use of new technologies, including green diesel fuels and innovative engine capabilities e.g. new catalytic converters.

Retrofitting technology to existing rolling stock can have mixed impacts. Some exhaust treatment systems work very well for reducing pollution but can have a very small increase in fuel consumption.

Sources of alternative fuels (e.g. biofuels) present a complex challenge from an environmental perspective. Not all are sustainable in the truest sense and can have detrimental environmental impacts elsewhere e.g. increased deforestation.

Digital railways can also play a significant role in reducing carbon emissions and supporting the new climate goals. Digital signalling (as planned for the East Coast programme) can reduce the whole life carbon footprint of signalling by up to 30% compared to conventional signalling. The digital system can also allow trains to run more efficiently, trains can run closer together, and the increased capacity could lead to modal shift.

There is no doubt that the railway faces many new challenges in the coming years. Doing business in a sustainable way is becoming ever more important in the face of climate change and there has never been a more important time to think about what the rail sector can do to support a green economic recovery from the pandemic. Everyone wants rail travel to be the cleanest, greenest form of mass transport for generations to come. As society emerges from the pandemic, it is important to 'build back better' and take a joined-up industry approach.

7e. Energy

Power up

Energy should feature today as one of the foundations of Maslow's hierarchy of needs. It powers the everyday delivery of our basic needs: food, water and warmth (or comfort and cooling), mobility; logistics could be added here also. The cost of energy and access to it dictate the ability to deliver the basic needs of society. On the other hand, energy is also the foundation of the industrial revolution that has also delivered major GHG emissions, air pollution, and energy inequities, namely those that can afford to access it and those that cannot. It has never been considered anything other than a commodity to drive to the lowest cost – until today. Mandated net zero, COP26 and the UN Sustainable Development Goals all see energy in a new light as the enabler to provide a route to decarbonisation and environmental balance for future generations.

Most governments have turned to technology as the saviour to reverse the years of misuse of other technologies that have delivered today's challenges. Innovation in technology has been at the forefront of all attempts to mitigate the challenge of GHG emissions. For example, as far back as the 1970s, technologies such as Carbon Capture and Storage (CCS) were highlighted as needed to arrest the impacts of CO_2 emissions but no traction was achieved until the 1990s: adding 'Usage' to make CCUS was not considered important until five years ago. The high cost of innovation was seen as a barrier as multiple governments withdrew support for what was seen as a much-needed transition technology to reduce GHG emissions. Today, over 30 years later, CCUS is seen as absolutely key to reducing the very large industrial decarbonisation clusters e.g. in Humber, South Wales, etc. The problem is not technology but economics and political will.

The drivers

Solar and wind all started with a very high price tag but with political will and subsidies they have now become cheaper than their fossil-fuel comparators. Energy storage is the current technology undergoing the same transformation, with EVs driving the cost of electricity storage down rapidly. The golden thread amongst all of these examples is that it has not been a technology challenge that has held up the advancement of the desired outcomes. Rather, it is the right governance, regulatory environment, standards, new market models and societal acceptance that have slowed progress. The UK was once at the forefront of many of these technology breakthroughs in CCUS, for instance. However, due to the wrong whole-system conditions (i.e. legislation, regulation, commercial market models, technical deployment and/or societal acceptance) the UK is now catching-up with others who took on the mantle of progress elsewhere.

In order to deliver technologies at scale that achieve the goal and deliver the outcomes desired, namely low-carbon, low-cost, low-environmental impact, more jobs, high societal acceptance, and high future proofing, there is a real need to adopt a whole-systems approach to our activities. Just announcing more stringent goals (e.g. 78% reduction by 2035) will not deliver it. You would not build a house on poor foundations, nor should we try to deliver technology without ensuring the foundations to support technology integration will act to deliver the outcomes desired.

Often, technologies solve one problem while creating another without enough consideration. Solar and wind displacing steam turbines was a great example. The implication for fossil-fuel steam turbines is that humans were able to command more power which was delivered if needed by all the users of the electricity grid. In contrast, it is nature which is in control of the wind and clouds to drive generation. This resulted in a need to dash for 'flexibility' – people turning things on and off to follow the wind and solar dips. Then storage was considered important to manage this risk.

Direct-Air Capture (DAC) aims to remove carbon from the atmosphere directly. Climeworks, a Zurich-based company, makes small car-sized DAC machines which draw air through a filter, much like a sponge. Once saturated, the filter is heated and the carbon is captured. The current cost is about £450-575 per tonne of CO_2 removed. Plans are afoot to suck 4,000 tonnes of CO_2 out of the air each year, which is equivalent to the annual carbon footprint of 600 people.

Who's in charge?

The energy system is one of the most complex machines in the world to rebuild as a green machine. It also needs to do so without being stopped. Think of this as trying to redesign and rebuild an aeroplane in flight. The entirety of the technological fabric of our energy systems from oil, gas, electricity and other vectors such as heating and cooling, all need to be reintegrated into a new operational model. The big challenge is that no one person, institution or government is in charge of this project! By definition, there cannot be any one system architect for this. This is a natural complex system-of-systems challenge – there is no Chief Executive Officer or Chief Technology Officer for the energy system. So how can this be delivered?

The foundations cannot be delivered with the governance infrastructure that exists today. Collaboration versus competition, regulated versus free market, private versus public, market driven versus government driven, national versus local – the list is endless. It demonstrates that the tensions and challenges that exist are all possible enablers or blockers to adopting technology at scale. The market has waited for 'market signals' from government while governments have waited for the market to demonstrate their commitment before indicating technology winners. The green machine is very much in need of a redesign and overhaul!

A clear vision of what good looks like is required. What is needed is: principal-based regulation – not micro-management regulation; whole-system analysis to allow a thousand solutions to bloom – not picking technology winners; enabling frameworks driven by all stakeholders – not the chosen few; and behaviour change – not of the public but of the establishment, amongst many others. These are some of the key ingredients that are required to allow collaborators, competitors and investors to make informed and transformational innovations across regulated and non-regulated markets, breakthrough business innovations, and technology savvy integrations – not just delivery.

There are many examples where these types of frameworks have demonstrated success without needing to know how it would be delivered. Who would have thought an empty phone with little functionality could end up managing your entire financial, emotional or technical life!

8 BUILDING GREEN ECOSYSTEMS

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A confluence of interests

The roles of digitisation and data have expanded to address decarbonisation and sustainability transformation. The confluence of organisational partnerships, transparency in the use of data-enforcement standards, and connectivity of an ecosystem of players is going to shape future relationships between public and private actors. This confluence will contribute to the building of green ecosystems designed to reduce the environmental impact of products and services.

Digital infrastructure serves as the foundation for an organisation's information, data and operations: it is increasingly playing a role in decarbonisation. The declining cost of sensors and cloud storage, as well as advances in tools that interpret and visualise data, are enabling organisations to manage carbon emissions better. By logging data throughout a value chain, organisations can gain visibility into the impact of sourcing decisions such as miles travelled and materials used in fabrication. The data enable organisations to stress-test business models to optimise and reduce carbon emissions. This has grown in importance as investors, consumers, industry peers and governments increasingly prioritise Environmental, Social and Governance (ESG) values.[xxviii] In order to maintain access to capital, comply with regulation and meet consumer demands, organisations will need to prioritise decarbonisation strategies and digital infrastructures for analysis and reporting.[xxix]

Data connectivity

Shifting our focus from decarbonisation of individual organisations or sectors to that of entire ecosystems, data connectivity and transparency becomes more critical. Data connectivity provides the ability to link disparate data sets that are crucial to interpreting information between organisations and across the value chain. Data transparency provides a level of confidence that the data are trusted and accurate. This can be further strengthened by standardised measurement and disclosure. An example of organisations working together to create transparency is the Partnership for Carbon Accounting Financials (PCAF). This industry-led partnership facilitates transparency and accountability of the financial industry to the Paris Agreement. The PCAF provides guidance on measurement and disclosure of financed emissions based on shared information and best practices from 16 financial institutions.[xxx] Aiding these transparency efforts is the proliferation of sector-agnostic technology that can improve data collection, immutability and analysis.

Data fabric, blockchain and the Internet of Things (IoT) are specific sector-agnostic technologies that will further enable information exchange and enforcement of standards of green ecosystems. Data fabric can help organisations better understand their decisions to support the transition to a low-carbon economy by bringing together disparate datasets from a variety of sources onto a centralised platform. Its ability to connect, combine and synthesise internal and external data makes it a powerful platform for anticipating future scenarios. By using data fabric to help measure and monitor financial exposure under different climate-related scenarios, organisations can gain visibility into how business decisions affect things like decarbonisation goals. This type of transparency into decisions will allow organisations to set goals and create frameworks and standards.

Blockchain is another technology that will further enable information exchange and enforcement of standards through the use of a distributed ledger that links transactions in secure blocks to show a history of what has happened in the chain before it. This has particular relevance when it comes to developing and maintaining sustainable supply chains as it provides the ability to verify participation across value chains. For instance, consumers wishing to buy low-carbon emission products can gain the necessary confidence needed when purchasing a product if blockchain technology can validate supply-chain standards. Ultimately, blockchain-enabled, forgery-

Public-private partnerships in innovation will continue to accelerate the pace of change for mainstream adoption of a decarbonisation agenda.

proof documentation could help mitigate 'greenwashing' i.e. the process of conveying a false impression or providing misleading information about how a company's products are more environmentally sound.[xxxi]

The IoT will play a role in decarbonisation through better information exchange and connectivity across the ecosystem's players. The IoT is the connection of devices to the internet using embedded software and sensors to communicate, collect and exchange data with one another. As an example, data from IoT sensors on public buses can improve modelling of commuter behaviours and optimise the routing of private transport to decrease carbon emissions.[xxxii] The three-sector agnostic technologies described (i.e. data fabric, blockchain and IoT) will play a critical role in decarbonisation strategies over the next decade.

Working together

Public and private actions will shape the use of these technologies for decarbonisation and spur further innovation to reduce carbon emissions.The private sector will help government regulation keep pace with how the private sector is collecting, managing and sharing its data in the public domain. Additionally, government will help align strategies. For instance, the UN Global Compact encourages organisations to adopt sustainable policies by providing frameworks and encouraging organisations to report on their implementation.[xxxiii]

Innovation in the public and private sphere will continue to reduce emissions as well. The private sector is already providing investment for innovative clean energy e.g Blackrock and Temasek committing to invest US$600 million in companies and technologies that will reduce carbon emissions.[xxxiv] Government-funded, applied research through programmes like Advanced Research Projects Agency–Energy (ARPA-E) will continue to provide the necessary support to fuel new carbon-related ideas.[xxxv] This research, along with contributions from academia and non-profits, will help to shape technologies and decarbonisation strategies. Public-private partnerships in innovation will continue to accelerate the pace of change for the mainstream adoption of a decarbonisation agenda.

9 THE GREEN SKILLS BOOM

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The challenge

The UK Government has made much about the potential growth in jobs due to green-energy development. But what is green energy, and why will there need to be a skilled workforce that differs from what we have today?

Simply put, green energy does not rely on the burning of fossil fuels to generate heat that is either used to turn generators to make electricity or heat water that circulates through pipes and radiators to warm buildings. Green energy utilises the forces of the winds, tides, the heat from the sun or the combustion of hydrogen, where water is the by-product. In some cases, it relies on the splitting or bonding of atoms, namely nuclear energy.

It is only in this current century that the realisation of the impact of burning fossil fuels on the climate has captured the attention of governments around the world. The climate-change summits of the past saw major powers move for and against a step-change in energy production and consumption. Many developing nations claimed that their growth relied on the need to continue to expand their use of fossil fuels. This situation is unsustainable in the long term: globally, we are moving to a doubling of our energy-supply requirements by 2050.

A significant challenge is the time it takes to develop the necessary workforce to meet the stated net-zero carbon emission targets by 2050 or earlier. The size of the challenge is enormous, with 29 million gas boilers heating homes in the UK, and 40 million fossil-fuel vehicles on our roads. Our housing stock is old and, in many instances, inefficient in the use of energy. Addressing the new build market alone will not scratch the surface as 80% of the housing stock already exists. There are estimated to be 26 million homes that need retrofitting to make them energy efficient. That is one and a half homes per minute if the 2050 deadline is to be hit. Additionally, rail, aviation and shipping technologies make heavy use of fossil fuels.

A straight replacement of fossil-fuel technology with green-energy solutions would still see the same amount of fossil fuel being extracted as at present. Energy reduction is a global challenge and is particularly difficult for a country like the UK lacking high levels of sunlight. We need a blended mix of technologies while at the same time reducing energy consumption.

A wide skills' base

This blended mix leads to the conclusion that our skills base must be broad enough to facilitate their adoption. The government's target to increase the offshore wind generation from 30 to 40 gigawatts brings with it a promise of 60,000 new jobs. The UK production by 2030 of 10 gigawatts of carbon-neutral hydrogen, created using renewable or carbon-capture energy, will again need a workforce with appropriate skills.

But are these really new jobs in the way in which they are being heralded? At the beginning of the century, much was made of

> ... without placing an urgent emphasis on the real catalyst for change, the need to cultivate the skilled workforce to develop, design, install and maintain the new technologies to reach the 2050 targets, change will not occur.

the need for new entrants in the plumbing sector to manage the introduction of condensing boilers and solar thermal hot-water systems. The reality was that because of the adoption of these technologies those who were displaced went on to retrain and fill the new roles that were required to meet demand. It is important to note that they did not come quickly to this market but gradually migrated as demand drove their need to respond. This behaviour will be replicated as a workforce currently working in a fossil-fuel environment adapts to take on the different skills necessary to thrive and prosper in a green-energy environment. There will be those who cannot or will not take on these new skills and will either move into different occupations or retire from the workplace. They will require replacements and this is where the real opportunity for future generations will emerge.

The need for innovation to tackle many of the challenges that will arise in a green-energy marketplace will, of course, be a necessity. But again, the innovations currently being conducted in the fossil-fuel environment will rapidly decline in response to that shift. Here too there will be a migration rather than the emergence of new roles.

So, just as one requires a blended mix of energy solutions, it is important to adopt an attitude of blended development for the workforce to support its emergence. Delivery of skills-broadening programmes that support the existing workforce to adapt to the new technologies will be required. These programmes will be necessary to provide the workforce geared to the production of green energy and its application in the domestic, commercial and industrial sectors. Concurrently, education and training programmes for new entrants into the workforce should incorporate the knowledge, skills and behaviours related to green-energy solutions. Through these programmes, it will be possible to enhance the learner’s opportunities in order to build a career in a carbon-neutral society.

Yet, like the adoption of so many technological innovations, the real driver will be the emergence of demand. This demand will be for products, services and solutions to support the drive to the 2050 targets. Without incentives, such as the feed-in tariffs or the green deal, none of which created the critical mass necessary for wide-scale adoption, it will be necessary to establish a change coalition. For this, we need to articulate the imperative for change and empower those who have embraced green-energy living to advocate a wider audience.

Environmentalists have expressed concern that change is coming too slowly to the green-energy agenda. Be that true or not, it is clear that without placing an urgent emphasis on the real catalyst for change, the need to cultivate the skilled workforce to develop, design, install and maintain the new technologies to reach the 2050 targets, change will not occur.

10 CONCLUSION AND RECOMMENDATIONS

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The overarching aim of this report has been to highlight the important role that technology can play in decarbonisation. Technology is a lever, albeit just one lever, that can be pulled when reducing emissions in a meaningful timeframe. Innovation is one of humankind's strongest assets and it will be possible to shift the dial by bringing the best of science and technology to the wheel of progress but it will need a concerted and coherent effort across many fronts. To be at the scale necessary to meet carbon-reduction objectives, technologies and other measures will need to achieve a ten-fold increase in cuts to emissions compared to those of 2016-2019.

Each of the four broad areas of relevant technologies described in this paper – adaptation, renewables, energy efficiency and carbon removal – has a place to play in achieving carbon-reduction targets. Industry sectors are picking up speed to deliver results as companies become increasingly concerned about the immediate impact of climate change on their operations, the expectation of more regulation around the issue, the realisation that there is a growing risk of litigation if they do not comply and, finally but positively, the recognition that technological change will create opportunities to become more competitive.

There are encouraging signs and actions. Investors are helping drive the momentum.[xxxvi] The expectations of the financial markets in respect of ESG investment criteria are growing more potent. As capital pours into stocks at the forefront of the transition to net zero, it drives down the cost of capital making it easier for business to attract investment. That will, in turn, help speed up the rollout of new technologies and incentivise others to adapt their business models. UBS, for instance, expects EVs to reach price parity with fossil-fuel vehicles in 2025, whereupon demand is likely to become exponential and hence boost innovation. Suitable investment at scale will also allow the installation of more than a million heat pumps a year rather than around 30,000 currently. As with the adoption of so many technological innovations, the real driver will be the emergence of demand. Businesses will respond to consumer demand for greener, 'do no harm', sustainable products and services. This impetus may become the biggest driver for change because if businesses do not keep up they risk losing their patrons.

There is a myriad of new jobs associated with a low-carbon economy but that may be cold comfort to redundant gas engineers or steelworkers if there is not the training and upskilling available for adaptation to occur. Workers in traditional carbon-intensive sectors may find it difficult to transition to skilled roles in new technologies without considerable help. This may impede any levelling-up agenda and will be sure to cost taxpayers.

As this report highlights, the foundations of a net-zero world cannot be delivered with the governance infrastructure present today. 'The market has waited for 'market signals' from government while governments have waited for the market to demonstrate their commitment before indicating technology winners. The green machine is very much in need of a redesign and overhaul!' It is a powerful message that speaks to the need to combine technologies with strategies as neither can deliver alone.

The report has three main recommendations:

- More investment is made in innovation to drive technologies that will help speed up carbon-emission reductions.
- More investment is directed at job upskilling and employment transition.
- More cross-silo working is encouraged, both top down and bottom up, in order to deploy faster, more resilient and more universal technological solutions.

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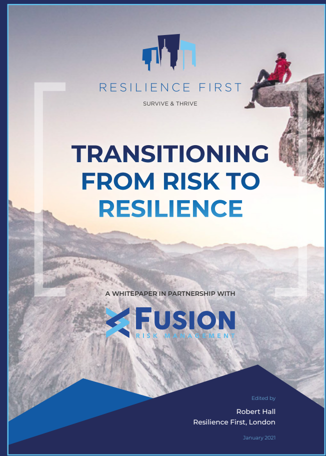

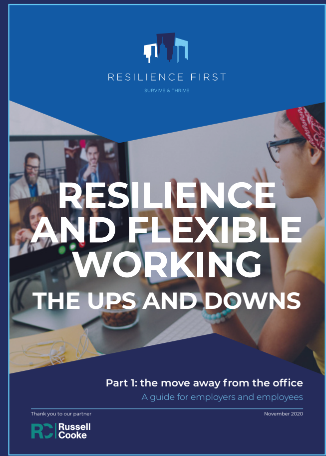

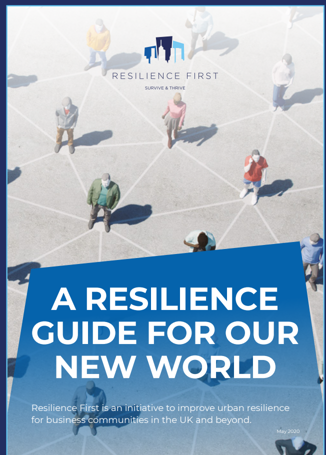

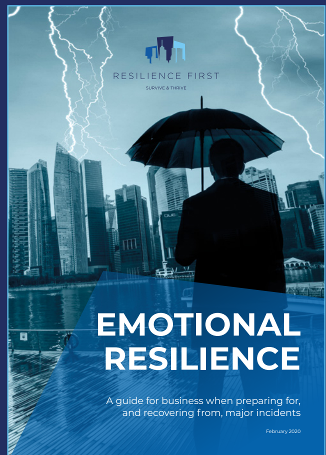

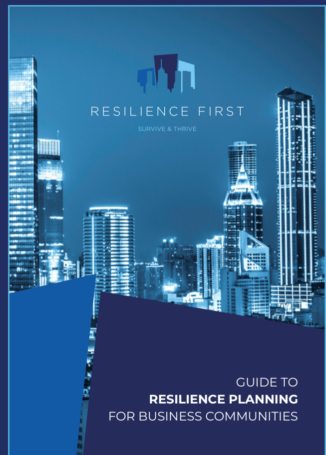

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